

Navy Personnel Research and Development Center

San Diego, California 92152-7250

TR-98-1

October 1997



An Evaluation of Three Computer Based Instructional Strategies in Basic Electricity and Electronics Training

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DTIC QUALITY INSPECTED 4

19971204 092

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is limited to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding the burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE October 1997	3. REPORT TYPE AND DATE COVERED Final	
4. TITLE AND SUBTITLE An Evaluation of Three Computer Based Instructional Strategies in Basic Electricity and Electronics Training		5. FUNDING NUMBERS Program Element: 0603707N Work Unit: R.1772.ET003	
6. AUTHOR(S) Stephen W. Parchman, John A. Ellis, Daniel Christinaz, Merle Vogel			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Navy Personnel Research and Development Center 53335 Ryne Road San Diego, California 92152-7250		8. PERFORMING ORGANIZATION AGENCY REPORT NUMBER NPRDC-TR-98-1	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Chief of Naval Research (Code 34) 800 North Quincy Street Arlington, VA 22217-5660			
11. SUPPLEMENTARY NOTES Functional Area: Training Research Product Line: Schoolhouse Training Effort: Schoolhouse Productivity			
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.		12b. DISTRIBUTION CODE A	
13. ABSTRACT (Maximum 200 words) Job requirements for Navy enlisted electronic technicians include extensive knowledge of basic electricity and electronic (BE/E) fundamentals. Historically the BE/E material has proved difficult for trainees to learn and has resulted in high setback and attrition rates. The objective was to evaluate alternative computer-based instructional strategies for teaching complex technical content. There were four instructional conditions: computer based drill and practice instruction (CBDP), enhanced computer based instruction (ECBI), a computer-based adventure game (GAME), and the existing classroom instruction (CI). The trainees were evaluated on the schoolhouse comprehensive test, a specially designed cognitive skills test, and a motivation questionnaire upon completion of the instruction. In addition, time to complete the instruction was recorded and analyzed. In general the CBDP and CBI groups outperformed the CI and GAME groups on all measures. The GAME condition performed no better than the CI condition. When there were differences between the ECBI and CBDP groups, the ECBI group performed better.			
13. SUBJECT TERMS Computer-based instruction, evaluation, motivation		15. NUMBER OF PAGES 25	
		16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED	20. LIMITATION OF ABSTRACT UNLIMITED

Foreword

The evaluation of alternative instructional strategies in the Aviation Avionics (AVA) Class "A" School was conducted under the 6.3 Manpower, Personnel, and Training Advanced Technical Development Program Element 0603707N (Work Unit 0603707N.R1772.ETO03). The work began in October 1990 and was completed in September 1993. The goal was to evaluate the effectiveness of three computer based delivery strategies in an operational training environment.

The authors would like to thank ATC William Kelsey from the Aviation Avionics "A" School, Naval Air Station, Memphis, TN for his assistance in collecting and analyzing data for this study.

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Summary

Background and Problem

Job requirements for Navy enlisted electronic technicians include extensive knowledge of electricity and electronic fundamentals. Training in basic electricity and electronics (BE/E) fundamentals is the first experience most trainees have in the domain. This curriculum is taught to over 12,000 trainees in 21 separate Navy Class "A" Schools. Historically the BE/E material has proven difficult for trainees to learn and has resulted in high rates of setbacks and attrition.

Innovations in computer based instruction and computer based games indicate that these approaches may prove to be beneficial for complex content such as basic electricity and electronics. Gaming and game embellishments such as animated graphics, video, and high quality sound are being introduced into educational software because it is assumed that such features will help sustain motivation over the long periods of time needed to achieve competence in complex skills. Furthermore, a number of studies have found that computer based instruction is both efficient and effective.

Objectives

The objective of this effort was to evaluate alternative computer-based instructional strategies for teaching complex technical content. Specifically, the study compared student performance and motivation in three different computer-based instructional conditions with standard Navy classroom instruction at the Aviation Avionics "A" School, Naval Air Station, Memphis, TN.

Method

Eighty trainees completed the instructional content which covered 4 days of an electronics curriculum. Trainees were randomly assigned to one of four instructional treatments designed to teach the same content: Computer based drill and practice instruction (CBDP, $n = 13$), enhanced computer based instruction (ECBI, $n = 23$), the game (GAME, $n = 20$), and the existing classroom instruction (CI, $n = 24$). The trainees were administered the schoolhouse comprehensive test, a specially designed cognitive skills test, and a motivation questionnaire upon completion of the instruction. In addition, time to complete the instruction was recorded and analyzed.

The CBDP instruction included the graphics and visualizations found in the instructor guide for classroom instruction. In this condition, the trainee could receive unlimited drill and practice in vocabulary as well as problem solving for unknown circuit values. The CBDP curriculum emphasis was on learning definitions and on learning procedures for solving problems.

The ECBI instruction illustrated BE/E concepts with computer generated graphics and animated simulations. As with the CBDP, the trainee could receive unlimited drill and practice in vocabulary and in solving for unknown circuit values. However, the

emphasis was on learning how circuit components interact to accomplish circuit functions.

The GAME was designed to resemble popular arcade games. It was a role playing game in which the learner assumed the role of a character in a fantasy world. The GAME's scenario centered on a fictional Navy ship that is blasted from the future to the present. The mission of the player was to find the resources needed to repair the ship's systems and return it to the future. Accomplishing this goal required that the trainee traverse a number of compartments by answering questions and solving problems. Each compartment addressed a single concept or instructional objective. To leave a compartment, a trainee must have completed an instructional exercise that was cast in the fantasy of the game.

In the Classroom Instruction (CI), instructors at the Avionics "A" School taught from a Navy approved instructor guide. The instructor guide was part of a highly structured curriculum, which specified the subject matter, the order of presentation, and the training aids to be used for each lesson.

Results

In general the CBDP and ECBI groups outperformed the CI and GAME groups on all measures. The findings support the hypotheses that (1) the CBDP and ECBI computer based instructional strategies are more effective than current classroom instruction, (2) the CBDP and ECBI computer based instructional strategies are more efficient than current classroom instruction, (3) all three computer based instructional strategies are more motivating than current classroom instruction, and (4) there are differences in effectiveness and efficiency among the computer based instructional strategies with the GAME condition performing no better than the CI condition. When there were differences between the ECBI and CBDP groups, the ECBI group performed better. However, performance on the quantitative knowledge component of the cognitive skills test was below passing for all groups.

Conclusions

The findings have implications for the design and development of computer based instruction. First, instructional developers should not overdevelop their curriculum. The complex visualizations used in the ECBI lessons did not significantly improve performance on the concept definition and symbol identification tasks. Unnecessary visualizations serve only to increase course length and development costs. However, visualizations did prove effective in the ECBI group when they were used to illustrate cause and effect relationships and make invisible concepts visible. Second, the poor performance on the quantitative knowledge component of the cognitive skills test may be attributable to trainees not having enough opportunities for practice. All trainees received the same fixed amount of practice. If they were unable to complete three problems correctly, they were "told" that they should practice more problems of that type on their own and advance to the next topic. Apparently, most trainees did not practice additional problems on their own. The computer based instructional programs could

have required trainees to practice until a mastery criterion had been achieved. Finally, the GAME was extraordinarily expensive to produce and difficult to debug. Because of a lack of experience in developing training oriented games, the GAME was conceptualized without regard for potential programming challenges. The result was that the GAME was no more effective than classroom instruction, but was much more expensive. Ideally, game components should provide the motivation needed for instruction while at the same time not distracting the trainees. On the other hand, an instructional design that maximizes instruction often interrupts the flow of the game fantasy. Integrating instruction and gaming requires a delicate balance between gaming and instruction to prevent one component from overwhelming the other. There is clearly a need for more research before games can be recommended as a source of instruction.

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Introduction

Problem

Basic Electricity and Electronics (BE/E) fundamentals constitute the first instructional modules in the curriculum of 21 Navy Class "A" Schools. Historically, the BE/E material has proven difficult for students to learn and has resulted in high setback and attrition rates. In recent years, some "A" Schools have experienced setback rates as high as 60 percent and attrition rates of up to 25 percent for the BE/E portion of the training. Research at this Center has found that BE/E graduates failed over half of the items on applied skills tests derived directly from the BE/E course materials (Parchman, Ellis, & Montague, 1990). Recent innovations in computer based instruction and computer based games indicate that these approaches may prove to be beneficial for complex content such as basic electricity and electronics. For example, gaming has become an increasingly prevalent technique used by instructional courseware developers to increase time on task and motivation (Malone, 1981; Dunne, 1984; Lepper, 1985; Lepper & Chabay, 1985; Lepper & Malone, 1987; Malone & Lepper, 1987; Brown, 1994). Numerous reviews have found that computer based instruction is both efficient and effective. (Bangert-Downs, Kulik, & Kulik, 1985; Chambers & Spreecher, 1980; Kulik, Bangert, & Williams, 1983; Kulik, Kulik, & Bangert-Downs, 1985; Kulik, Kulik, & Cohen, 1980; Kulik & Kulik, 1986; Kulik & Kulik, 1987; Neimiec & Walberg, 1987; Orlansky & String, 1979; Roblyer, 1988)

Background

The efficacy of computer based instruction (CBI) has been evaluated and is well documented. Kulik (1994) reviewed the data from a large number of studies and concluded that:

- **Students learn more.** CBI improved achievement scores by 0.35 standard deviations, or from the 50th percentile to the 64th percentile, for all studies.
- **Students learn in less time.** CBI reduced instruction time by an average of 34 percent in 17 studies of college instruction and 24 percent in 15 studies of adult education.
- **Students like their classes better.** CBI improved attitudes toward instruction by 0.28 standard deviations in 17 studies.

Recent research has found that teaching content using computer games can also be beneficial. Gaming and game embellishments such as animated graphics, video, and high quality sound are being introduced into educational software because it is assumed that such features will help sustain motivation over the long periods of time needed to achieve competence in complex skills (Randel, Morris, Wetzel, & Whitehill, 1992). Their findings indicate that when games were used in instruction:

- **The trainees learned the same amount as in traditional classroom instruction.** In 63 comparisons, they found that achievement improved in 22 studies, remained the same in 38 studies, and decreased in three studies.
- **Students liked their classes better.** In 12 of 14 studies, trainees reported more interest in the game based instruction than in traditional classroom instruction.
- **Students remembered better than traditional classroom instruction.** In 14 studies measuring retention, they found that retention was better in 10 and remained the same in four.

The present study evaluates three different computer based strategies for basic electricity and electronics training. The first strategy is computer based drill and practice (CBDP). The trainee is instructed using text passages and graphics with all key vocabulary items in bold font. As trainees progress through the instruction, they review and practice vocabulary and problem solving. Simulations are not used and graphics are simple one or two colored annotated line drawings. The instruction does not make full use of the computer's capability to illustrate concepts with graphics and simulations.

The second strategy is enhanced computer based instruction (ECBI). The trainee is instructed using attractive and compelling text, graphics, animation, and simulations to illustrate the subject matter. It makes full use of the computer to visually illustrate concepts and to direct the trainee's attention to the pertinent aspects of the subject matter. As with the CDP environment, trainees are provided reviews and are quizzed as they progress through the instruction using embedded questions and a variety of problem solving tasks.

The third strategy is a computer based adventure game (GAME). It implements the elements found in successful games. GAME is a role playing game where the trainee assumes the role of a character in a fantasy world. The fantasy world is a battleship from the future. The battleship is composed of compartments and the trainee must visit all of the compartments. Within a compartment, a trainee can explore and discover objects and various sorts of characters. To "escape" from a compartment, the trainee must complete an exercise that is cast within the fantasy of the game. The instruction for a compartment consists of an advanced organizer, execution of the exercise, and a summary of the concepts conveyed by the exercise. The advanced organizer and summary are typically delivered by a fantasy character who serves as the trainee's guide and advisor through the adventure.

Research Questions

The research questions are:

- Are the computer based instructional strategies more effective than current

- Are the computer based instructional strategies more efficient than current classroom instruction?
- Are the computer based instructional strategies more motivating than current classroom instruction?
- Are there differences in effectiveness and efficiency among the computer based instructional strategies?

Objective

The objective is to evaluate alternative instructional strategies for teaching complex technical content. Specifically, the study compares student performance and motivation in four different instructional conditions: (1) computer based drill and practice, (2) enhanced computer based instruction, (3) computer based instructional games, and (4) traditional classroom instruction.

Method

Subjects

The subjects were 88 trainees at the Aviation Avionics "A" School, Naval Air Station at Memphis, Tennessee. Trainees were selected to become avionics technicians on the basis of their Armed Services Vocational Aptitude Battery (ASVAB) scores; therefore, the subject population was relatively homogeneous. The trainees were assigned randomly by class to one of the four instructional conditions: CBDP ($n = 14$), ECBI ($n = 25$), Game ($n = 25$), Classroom ($n = 24$). All trainees had completed the first 5 weeks of the Avionics "A" School curriculum and had taken five end-of-week tests. Trainees in the CBDP, ECBI, and GAME conditions then received experimental instruction outside of the standard "A" school classroom. Upon completion of the experimental curriculum, they returned to the regular course.

Trainees with incomplete or missing data were omitted from the study. Trainees were omitted because of sickness, legal problems, or were dropped from the course for achievement, administrative, or disciplinary reasons. Trainees with complete data numbered 80. The final number per instructional condition was CBDP ($n = 13$), ECBI ($n = 23$), Game ($n = 20$), Classroom ($n = 24$).

Design

The research design selected was a quasi-experimental, four group, posttest-only design. The four treatment groups were:

1. **Computer Based Drill and Practice:** Trainees received the CBI instruction and were then given a battery of dependent measures.

2. **Enhanced Computer Based Instruction:** Trainees received the ECBI instruction and were then given a battery of dependent measures.
3. **GAME:** Trainees received the GAME instruction and were then given a battery of dependent measures.
4. **Classroom Instruction:** Trainees received the regular course of instruction and were then given a battery of dependent measures.

Dependent Measures

Pre-Measures

A pre-training measure of performance was calculated for each subject. This measure was the mean score achieved on the five weekly Aviation Avionics "A" School course tests completed prior to beginning the experimental curriculum.

Post Measures

The trainees were administered two different achievement tests upon completion of the instruction: a schoolhouse developed test (Schoolhouse Test) and a test developed by DPRDC (NPRDC Test).

The Schoolhouse Test tested 13 of the 25 task statements covered by the course objectives. The DPRDC Test tested all 25 task statements. The DPRDC Test had four parts:

1. Knowledge of definitions.
2. Knowledge of symbols.
3. Qualitative knowledge.
4. Quantitative knowledge.

The trainees also were administered the ARCS motivation questionnaire developed by Keller (1989). The ARCS was used to measure the trainees' perceptions of the motivational characteristics of the instruction. It has four subscales designed to measure the degree to which the instructional materials address the motivational components of attention, relevance, confidence, and satisfaction. The reliability of the ARCS given by Cronbach's alpha is .89 for attention, .90 for confidence, .81 for relevance, .92 for satisfaction, and .96 for overall motivation.

Instructional Content

The content covered 4 days of the 143 day Aviation Avionics "A" School electronics curriculum. The 4 days of instruction included lessons on capacitance, capacitors, and resistance-capacitance (RC) circuits using direct current (DC) as the source. The

instruction covered two learning objectives and 25 specific learning tasks. The tasks included knowledge of terms and symbols, physical characteristics of electrical components, and safety precautions, as well as problem solving.

Instructional Treatments

There were four instructional treatments. All four treatments were designed to teach the same content. The computer based drill and practice instruction (CBDP) and enhanced computer based instruction (ECBI) treatments were developed by the authors at the Navy Personnel Research and Development Center (NPRDC). The game (GAME) treatment was developed by NPRDC and contractor personnel. The classroom instruction (CI) was the existing lecture-based class taught by the school instructors.

Computer Based Drill and Practice Instruction

The CBDP instruction was designed to parallel the current classroom instruction. It included only the graphics and visualizations found in the instructor guide for the capacitance and RC portions of current instruction. In addition, the trainee could receive unlimited drill and practice in vocabulary and problem solving for unknown circuit values. The emphasis of the CBDP curriculum was on learning definitions, concepts, and procedures for solving problems.

The CBDP curriculum was a series of lessons consisting of a text passage and questions on a particular concept or procedure. When the trainee answered correctly, the system displayed "Correct." The feedback after an incorrect answer depended on the number of tries. If the trainee's first response was incorrect, the system displayed "Wrong-Try Again." If the second attempt was incorrect, the system displayed the message "Wrong" and showed the trainee an annotated step by step solution to the problem. "HELP" was available at all times. If the trainee asked for "HELP," the system displayed an annotated problem that was similar to the problem being studied. Each trainee was required to repeat each problem type a minimum of three times before being advanced. However, trainees could opt to work as many additional problems as they thought necessary.

The CBPD incorporated four drill and practice learning strategies. The first strategy, the vocabulary definition strategy, simulated flash cards. This strategy presented each vocabulary word in the lesson in succession with its full definition. This allowed the trainee to read through each definition before being quizzed. The second strategy was definition building. For this strategy, the trainee constructed the definition of a vocabulary item by selecting phrases from a menu. The menu contained one phrase from a target definition and phrases from other related words in the lesson. The third strategy was hidden multiple choice. For this strategy, the trainee viewed each definition one at a time and indicated whether or not it was the correct definition. The fourth strategy was visible multiple choice. In this strategy, the trainee selected the correct definition from a list of related word items found in the lesson.

The CBDP also provided drill and practice in both qualitative and quantitative problem solving. For qualitative exercises, the trainee read a description on how a circuit worked and was asked questions about qualitative relationships. For quantitative exercises, the trainee was asked to apply the appropriate formula to solve for unknown circuit values. A class of 14 trainees was assigned to the CBDP treatment. The trainees received CBDP until they had completed the instruction on capacitors, capacitance, and RC circuits.

Enhanced Computer Based Instruction

The Enhanced Computer Based Instruction (ECBI) took advantage of the computer to illustrate concepts with graphics and animated simulations. As with the CBDP, the trainee could receive unlimited drill and practice in vocabulary and solving for unknown circuit values. However, the emphasis was on learning how circuit components interact to accomplish circuit functions.

The ECBI treatment was similar to the CBDP treatment. The curriculum was a series of lessons consisting of a text passage, graphics, animated simulations, and questions. When questions were asked and the trainee gave a correct answer, the system displayed "Correct." The feedback after an incorrect answer depended on the number of tries. If the trainee's first response was incorrect, the system displayed "Wrong-Try Again." After three attempts, the system told the trainee to review the explanatory text. "HELP" was available at all times. If the trainee requested help, the system displayed an annotated problem that was similar to the problem being studied. Trainees were required to repeat each problem type at least three times. If a trainee failed three out of five problems, the program instructed the trainee to review the explanatory text and examples and work more problems. As with the CBDP, trainees could work as many problems as they thought necessary. A class of 25 trainees were assigned to the ECBI treatment. The trainees received ECBI until they had completed the instruction on capacitors, capacitance, and RC circuits.

GAME

The GAME was designed to resemble popular games such as "Kings Quest V" (Williams, 1990) and "3 in Three" (Johnson, 1990). Like these, the GAME was a role playing game in which the learner assumed the role of a character in a fantasy world. The GAME's scenario centered on a Navy ship that was blasted from the future to the present. The mission of the player was to find the resources needed to repair the ship's systems and return to the future. Accomplishing this goal required that the trainee traverse a number of compartments. Each compartment addressed a single concept or instructional objective. To leave a compartment, a trainee must have completed an instructional exercise that was cast in the fantasy of the game. The trainee's path through the compartments was constrained by the structure of the content to be learned.

A typical instructional sequence for a single compartment consisted of an advanced organizer, exercises, and a summary of the topics to be covered in the compartment. Depending on the task, some or all of the trainees would require more than the brief

introduction in the advanced organizer to complete the exercise. In these cases, additional instruction and information was provided through a "classroom" that was available to the trainee at any point in the game. The "classroom" operated in two modes; exploratory mode and direct mode. In exploratory mode, the trainee was free to explore, in a hypertext environment, the topics addressed in the compartment. The hypertext environment consisted of a series of topics and a presentation for each topic. Within each presentation were links to other topics and presentations. In direct mode, the trainee received linear CBI on the topics addressed in the compartment. A linear CBI lesson consisted of frames containing instruction on the compartment's focus. Embedded questions were used to maintain attention and ensure comprehension. Both modes took advantage of the computer to illustrate concepts with graphics and simulations such as those employed by Hollan, Hutchins, and Weitzman (1984). Schematic diagrams were used to illustrate circuits. Practice exercises in problem solving and reasoning required the trainee to solve problems and conduct observations on simulated circuits. A class of 25 trainees were assigned to the GAME treatment. The trainees played until they had completed the instruction on capacitors, capacitance, and RC circuits.

Classroom Instruction

In the Classroom Instruction (CI) condition, instructors at the Avionics "A" School taught from a Navy approved instructor guide. The instructor guide provided a structured curriculum, which specified the subject matter, the order of presentation, and the training aids to be used for each lesson. Instructors were encouraged to personalize each lesson. Personalization consisted primarily of providing examples from the instructors personal experiences that supported the curriculum. The instructor was expected to be a subject matter expert. Typically, questions raised in the classroom were resolved by the instructor. The trainees were provided with trainee guides to assist in learning. Trainees who had difficulties were counseled and given additional instruction and/or time to study. A class of 24 trainees was assigned to the CI treatment. The trainees were instructed by Navy instructors until they had completed the instruction on capacitors, capacitance, and RC circuits.

Procedure

Trainees were under instruction from 0700 to 1530 daily with a 1 hour break for lunch. Since the CBDP, ECBI, and the GAME groups were self-paced, trainees were told they could break whenever they felt it was necessary. All trainees in a particular class were assigned the same instructional program. All trainees were told that they would be learning about capacitors, capacitance, and RC circuits using computer based instruction. It was emphasized that their performance counted toward their success/failure in the course. The trainees understood that their grade would be entered into their military record. Trainees who failed the Navy developed comprehensive progress test were either "set-back" to repeat the CI curriculum or remediated with tutorial instruction and then retook the exam. The trainees were told that the instructors would not be available for supplementary tutoring and that the trainees were responsible for completing all of the required homework found in the study guides. The resources available were two classroom instructors, study guides, fellow classmates, referenced

publications, paper, pencils, and calculators in accordance with Navy course regulations. The trainee groups were not aware of any differences in the experimental programs, and they were not aware that performance was being monitored. When subjects completed the program, they were allowed to review the material before being tested.

Results

Pre-Measures

An analysis of variance (ANOVA) compared the four groups on the mean score achieved on all "A" school course comprehensive tests (CCT) prior to beginning the experimental curriculum. There were no significant differences among the groups on this measure ($p < .05$). This measure was used as a covariate in subsequent analyses.

Post-Measures

Schoolhouse Test

An analysis of covariance was performed on the total percent correct for the Schoolhouse Test with the CCT as a covariate. Table 1 presents the adjusted means and standard deviations of the Schoolhouse Test. The analysis showed no differences among the treatment groups ($p < .05$). One reason is that only half of the tasks covered by the course objectives was assessed in the Schoolhouse Test. Further, an analysis of the test showed that many of the more complicated tasks and concepts were not tested.

Table 1

Mean Percent Correct Scores and Standard Deviations for the Schoolhouse Test and NPRDC Sub-Tests

	CBDP	ECBI	GAME	CI
Schoolhouse Test	84.17 SD = 12.40	82.00 SD = 10.87	84.78 SD = 10.70	88.29 SD = 10.21
Knowledge of Definitions	83.33 SD = 12.55	80.00 SD = 14.67	62.00 SD = 14.55	58.00 SD = 25.00
Knowledge of Symbols	92.00 SD = 10.81	84.54 SD = 15.00	83.27 SD = 14.45	77.27 SD = 25.98
Qualitative Knowledge	78.71 SD = 13.19	81.65 SD = 13.14	66.20 SD = 18.43	70.92 SD = 16.04
Quantitative Knowledge	54.61 SD = 29.00	57.92 SD = 23.61	52.06 SD = 22.15	60.94 SD = 24.27

NPRDC Test

A multivariate analysis of variance (MANOVA) with the CCT as a covariate was performed on the percent correct scores for each of the four sub-tests of the NPRDC test. There was a significant effect indicating significant differences among groups ($p < .01$).

Univariate ANOVAs were then calculated for each of the four sub-tests of the NPRDC test to determine group differences. The analysis of the knowledge of definitions sub-test showed significant differences among the groups ($p < .01$). Post hoc comparisons revealed that trainees in CBDP and ECBI conditions did not differ. However, CBDP and ECBI trainees significantly outperformed trainees in CI and GAME conditions ($p < .01$), which did not differ. The analysis performed on the symbol's sub-test showed no significant differences among the instructional conditions. The analysis for the qualitative knowledge sub-test found significant differences in performance among the groups ($p < .01$). Post hoc comparisons revealed that CBDP and ECBI trainees performed significantly better than trainees in the GAME condition ($p < .01$). Further ECBI trainees scored significantly better than trainees in the CI condition ($p < .01$). There were no differences between the CI and GAME conditions or the CBDP and ECBI conditions. Finally, the analysis for the quantitative reasoning sub-test showed no significant differences among the conditions. Table 1 presents the means and standard deviations for these analyses.

ARCS Motivation Questionnaire

A multivariate analysis of variance (MANOVA) was performed on the scores for each of the four scales of the ARCS motivation questionnaire (Attention, Confidence, Relevance, and Satisfaction). There was a significant effect indicating significant differences among groups ($p < .01$). Table 2 presents the means for the motivation analysis.

Table 2
Mean Scores for ARCS Motivation Questionnaire Scales

	CBDP	ECBI	GAME	CI
Attention	3.09	3.71	3.46	3.29
Relevance	3.44	3.55	3.36	3.34
Confidence	3.04	3.59	2.65	3.11
Satisfaction	2.81	3.23	2.93	3.04

Univariate ANOVAs were calculated for each of the four scales. For the Attention scale, there were significant differences among groups ($p < .01$). Post hoc comparisons showed that the ECBI and GAME conditions captured significantly more of the trainees attention than CBDP and CI conditions ($p < .01$). There were no significant differences between CBDP and CI groups or between the ECBI and GAME groups. There were no

differences among the groups on the Relevance scale. The analysis for the Confidence scale showed significant differences between groups ($p < .01$). Post hoc comparisons revealed ECBI trainees were significantly more confident than trainees in the other three conditions ($p < .03$). There were no differences among the CI, GAME, and CBDP groups. There were no differences among the groups on the Satisfaction scale.

Time

Table 3 presents the means and standard deviations for the instructional time for the CBDP, ECBI, and CI conditions. Unfortunately, there was an error in the computer program, and as a result, time data for the GAME group was lost. The data show that trainees in the CBDP and ECBI groups spent 26 percent and 28 percent less time in instruction, respectively, than trainees in CI group. Field notes taken by investigators during the study indicate that trainees in the GAME group spent about the same amount of time completing the instruction as trainees in CI group.

Table 3

Mean Time in Hours and Standard Deviations for Instructional Time for the CBDP, ECBI, and CI Groups

CBDP	ECBI	CI
16.37 Hours SD = 2.66	15.93 Hours SD = 3.24	22.00 Hours SD = 0.00

Discussion

The primary findings are that the CBDP and ECBI groups in general out performed the CI and GAME groups on all measures: course tests, motivation, and time. "Yes" is the answer to all four research questions.

- Are the computer based instructional strategies more effective than current classroom instruction?
- Are the computer based instructional strategies more efficient than current classroom instruction?
- Are the computer based instructional strategies more motivating than current classroom instruction?
- Are there differences in effectiveness and efficiency among the computer based instructional strategies?

When there were differences between the CBDP and ECBI groups, the ECBI group performed better. However, it should be noted that performance on the quantitative sub-

test of the NPRDC test was low for all groups, and no group achieved a mean passing score.

The differences between the self-paced computer groups (CBDP and ECBI) and the CI group were expected and are consistent with a large number of previous studies (e.g., Kulik, Kulik, & Shwalb, 1986). However, the reasons why the ECBI condition generally performed better and why the GAME condition failed to do better than the much more cost effective CI condition need to be examined.

ECBI Group Performance

ECBI trainees generally learned more effectively, more efficiently, and were more motivated than the other three groups. There are several possible explanations for these results. First, the ECBI treatment was more task oriented while the CBI and CI were more topic oriented. Task oriented instruction has been found to be more effective in learning, retention, and performance than topic oriented instruction (Collins, Brown, & Newman, 1989; Cognition and Technology Group at Vanderbilt, 1990; Semb & Ellis, 1994). Second, the ECBI incorporated visualization techniques and simple simulations to illustrate cause and effect relationships and make invisible concepts visible. Research on learning from text and on computer based learning environments shows that simulation and visualization aid learning and retention if they supplement the curriculum in meaningful ways. Third, the ECBI provided the trainees with elaborations to illustrate how concepts and events are structured and function. Research on learning has shown that elaborations enhance a trainee's conceptual model of the curriculum. All of these factors are likely to have contributed to the enhanced performance and motivation of ECBI trainees.

GAME Group Performance

Games and simulations have a long tradition of use in the military where a simulated environment is substituted for the "real thing" when practice with the "real thing" is too expensive or dangerous. The GAME condition in this study departed from this tradition in that the game itself was the primary source of instruction. That is, the game presented all the facts, concepts, principles, and generalizations needed for instruction in the domain of capacitors, capacitance, and RC circuits. This approach resulted in performance that was no better than standard Navy classroom instruction. There are several possible explanations for this finding. The design goal for the GAME was to make it "competitive" with the best in the commercial market. This may have been a poor design choice. Additionally, the GAME generally suffered from technical flaws including software bugs, inaccurate technical content, poor instructional techniques, and interface problems. Many artistic effects were included that contributed little to its effectiveness. For example, in the GAME, each trainee was able to select a caricature of him or herself. The caricature "walked" through each compartment and picked up items, opened doors, etc. This caricature served no instructional purpose and was only a gaming embellishment. However, it was costly to produce, difficult to program, and was the source of many program bugs. In retrospect, the caricature was probably unnecessary. As suggested by Halff (1994), the GAME should not have been designed

to compete with the commercial market, but with the instructor, the transparency, and the chalkboard. There is a need for research that better delimits the characteristics of a "good" instructional game. Given these problems, it may be a positive finding that the GAME did no worse than the CI.

Conclusions

The findings have implications for the design and development of computer based instruction. First, the CBDP and ECBI groups were equally effective when used to teach symbols and definitions. This suggests that instructional developers should not overdevelop their curriculum. The complex visualizations used in the ECBI lessons did not significantly improve performance on these tasks. Unnecessary visualizations serve only to increase course length and development costs. However, visualizations did prove effective in the ECBI group when they were used to illustrate cause and effect relationships and to make invisible concepts visible. This is supported by the qualitative data ,which indicates that the ECBI strategy of using visualizations to illustrate cause and effect relationships was more effective than CBDP and CI, which used a math model and the manipulation of symbols as the basis for instruction.

Second, only a few trainees mastered the quantitative section of the test. A review of performance on the practice problems indicated that trainees did not have enough opportunities for practice. All trainees received the same amount of practice. They practiced each problem type a maximum of five times. Once they completed three problems of a problem type correctly, they were advanced to the next topic. If they were unable to complete three problems correctly, they were "told" that they should practice more problems of that type on their own, but still were advanced to the next topic. Apparently, most trainees did not practice additional problems on their own or, if they did, they continued to practice incorrectly. The computer based instructional programs could have required trainees to practice until a mastery criterion had been achieved.

Finally, the GAME was extraordinarily expensive to produce and difficult to debug. The cost of developing commercial video/arcade games ranges from \$250,000 to \$500,000 per minute. Because of a lack of experience in developing training oriented games, the GAME was conceptualized without regard for potential programming challenges. As a result, the programming team had difficulty anticipating which aspects of the design would be difficult to program (Halff, 1994). There is a need for more research before games are used as a source of instruction. Ideally, game components should provide the motivation needed for instruction yet not distract the trainee. On the other hand, an instructional design that maximizes instruction often interrupts the flow of the game fantasy. Integrating instruction and gaming requires maintaining a delicate balance of gaming and instruction to prevent one component from overwhelming the other.

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